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Eco-Driving Systems for Connected Automated Vehicles: Multi-Objective Trajectory Optimization

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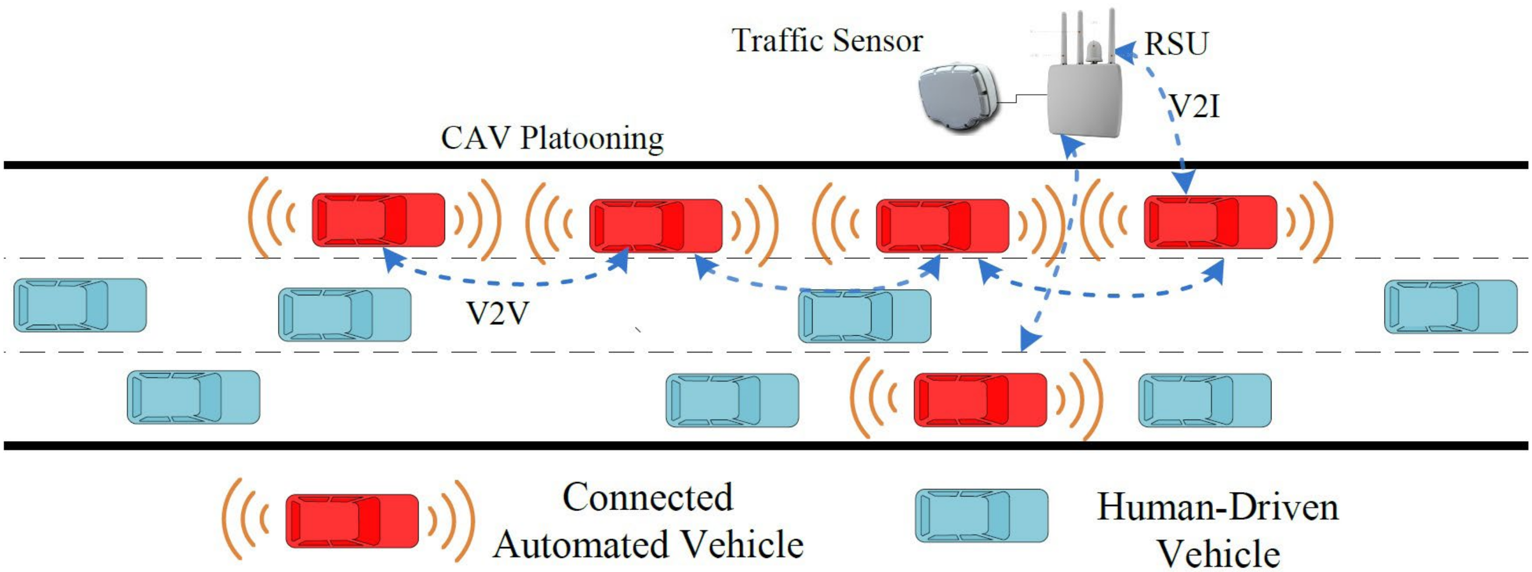

Connected automated vehicle (CAV) technology, which enables autonomous vehicles to communicate at high speed, has shown significant potential in improving fuel efficiency and safety in everyday transportation. This study leverages the advances of CAV technology to design an ecodriving and platooning system to improve both fuel and operational efficiency of vehicles on freeways. The proposed algorithm optimizes CAVs' trajectories with three objectives. These include travel time minimization, fuel consumption minimization, and traffic safety improvement.

Study Methods

We carried out the first stage of our control logic, designed for CAV trajectory planning, with two optimization models. The first model predicts freeway traffic states in the near future and accordingly optimize CAVs' desired speed profile to minimize total freeway travel time. Notably, the interactions between CAVs and human-driven vehicles (HVs) are described in the embedded traffic flow model, and the optimization can fully account for CAVs' impact to HVs' speeds. To support the proposed optimization model, this study implements a macroscopic traffic flow model. The model can predict future traffic state (speeds, flows, and density) given various CAV desired speed profiles. Then, grounded on the obtained speed profile, the second eco-driving model would further update it to platoon CAVs and minimize their fuel consumption. The powertrain control parameters, such as engine torque and brake force, are the key control parameters considered in the second model. Our proposed model considers aggregated fuel consumption minimization for a cohort of CAVs as our primary optimization objective.

We developed the second stage for real-time control purpose to ensure the operational safety of CAVs. Particularly, based on the speed profile from the first stage, real-time adaptions would be placed on CAVs to dynamically adjust speeds, in response to local driving conditions. This second stage would react to unpredictable local traffic perturbations. For example, as the CAV could adjust to a sudden lane change of nearby vehicles while maintaining fuel consumption minimization optimization objective.

The proposed control approach would minimize the aggregated fuel consumption of a cohort of CAVs on the highway, while maintaining a minimal average traffic time.

Findings

We used a VISSIM simulation for performance evaluations of the proposed models. Recognizing that a simulation model cannot accurately reflect reality until it is well-calibrated, we collected field data for calibration. Then, we used the VISSIM-COM interface to develop a program to execute the local adaption function using VB.NET; the MYSQL database was used to simulate the on-line operational procedure. The real-time traffic information is detected, and the target vehicle's trajectory is adjusted during the simulation.
Our experimental results showed that using the proposed models, we can achieve approximately 10% reduction in aggregated fuel consumption of the considered cohort of CAVs with penetration rate of 10%-30%, while the average traffic time is minimized.

Policy Recommendations

The proposed traffic time and fuel consumption minimization models are particularly useful in highway where CAVs penetration rate is at least 10%. Using the models developed in this work, we can achieve our main objective of minimizing aggregated fuel consumption for a cohort of CAVs, while also minimizing the average traffic time.

About the Authors

Dr. Huang is an Associate Professor in the Department of Electrical and Computer Engineering at San Diego State University. His research focuses on intelligent vehicles, very-large-scale integration (VLSI) testing and security, and computer-aided design of integrated circuits (ICs).

Dr. Yang is currently an Assistant Professor in the Department of Civil & Environmental Engineering at the University of Utah. His current research areas include machine learning application in transportation, evacuation planning and operation, traffic operations with connected automated vehicles, intelligent transportation systems, traffic safety, and network flow modeling.

To Learn More

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